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Fiscal Year 2005 Solar Radiometry and Metrology Task Accomplishments

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Fiscal Year 2005 Solar Radiometry and Metrology Task Accomplishments

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ABSTRACT

The National Renewable Energy Laboratory (NREL) Solar Radiometry and Metrology task provides traceable optical radiometric calibrations and measurements to photovoltaic (PV) researchers and the PV industry. Traceability of NREL solar radiometer calibrations to the World Radiometric Reference (WRR) was accomplished during Pyrheliometer Comparison at NREL in October 2004. Ten spectral and more than 200 broadband radiometers for solar measurements were calibrated this year. We measured detailed spectral distributions of the NREL and PV industry Pulsed Solar Simulators and are analyzing the influence of environmental variables on radiometer uncertainty. New systems for indoor and outdoor solar radiometer calibrations and ultraviolet (UV) spectral measurements and UV radiometer calibrations were purchased and tested. Optical metrology functions support the NREL Measurement and Characterization Task effort for ISO 17025 accreditation of NREL Solar Reference Cell Calibrations and have been integrated into the NREL quality system and audited for ISO17025 compliance.

1. Objectives

The project addresses technical challenges regarding analysis tools, access to data, uncertainty of analysis, standardization of assumptions, and characterization of solar resource on technologies. We provide technical expertise and input to standards and codes development to address technical issues regarding solar radiation data and measurements affecting the Fundamental Research, Advance Materials and Devices, and Technology Development components of the *Solar Program Multi-Year Technical Plan* for Flat Plate Photovoltaics, Concentrating Solar Power Systems, Solar Heating and Lighting, and New Concepts. Our objective is to provide best estimates of uncertainty and most accurate, as appropriate, optical radiation measurements and data that meet the needs of solar researchers and industry partners.

2. Technical Approach

Our approach is to meet solar research and industry needs in optical calibrations and measurements by providing calibrations and data of known uncertainty that is traceable to national standardizing laboratories and internationally recognized reference standards, such as the National Institute of Standards and Technology (NIST) Standard of Spectral Irradiance and the World Radiometric Reference (WRR). We participate with consensus standards organizations, in accordance with Office of Management and Budget Circular OMB A-119.[1] These include the American Society for Testing and Materials (ASTM), International Standards Organization (ISO), and International Lighting Commission (CIE), which develop standards ensuring high-quality solar energy industry products. Reference standard and working instruments and systems are characterized and calibrated with documented procedures against national and international standards with as short a "traceability chain" as possible to accurately quantify and reduce uncertainties. Calibrations, measurements, and technical expertise are provided on a programmed and as-requested basis to meet the requirements for ISO 17025 accreditation.

3. Results and Accomplishments

Accomplishments include the following: (1) verified the stability of NREL solar radiometric reference with respect to the WRR, (2) characterized pulse solar simulator spectral distributions, (3) tested models to account for environmental influences on zero drift of pyrheliometers to measure direct solar beam, (4) tested new broadband radiometer calibration systems for outdoor and indoor calibrations, and spectral UV measurements, and (5) specified and selected new spectroradiometer system to replace obsolescent systems used in PV Measurements and Characterization task for Reference PV Cell calibrations. Successful external and internal audits resulted in the ISO 17025 accreditation for two activities in the PV Measurements and Characterization task.

3.1 WRR Traceability

The project supported the NREL Pyrheliometer Comparison (NPC) Sept. 27 - Oct. 8, 2004. Twenty-three instruments were compared to NREL's *transfer standard group* (TSG) of absolute cavity radiometers that participated directly in International Pyrheliometer Comparisons (IPC) of the World Meteorological Organization (WMO). Pooled standard deviation of the TSG radiometers (with four from NREL) was 0.06%, confirming excellent stability of the NREL solar radiometric references. Figure 1 shows typical WRR transfer data for a participating cavity radiometer.

3.2 Pulse Solar Simulator Characterization

The Pulse Analysis Spectroradiometer System (PASS) was upgraded with a more efficient integrating-sphere input, and was used to classify NREL and industry (Spire Corp., Shell Solar) flash simulators according to ASTM standard E-927. Figure 2 shows the ratio of new signal to old for the upgraded PASS input optics. We replaced the older barium sulfate ($BaSO_4$)-coated integrating sphere with a spectrolon sphere.

[1] see http://www.whitehouse.gov/omb/circulars/a119/a119.html

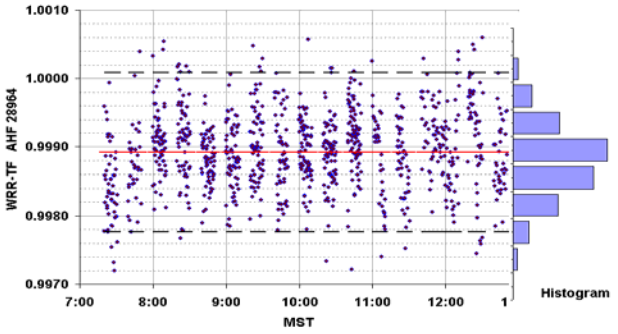

Fig. 1 Typical WRR transfer factor data for NPC 2004.

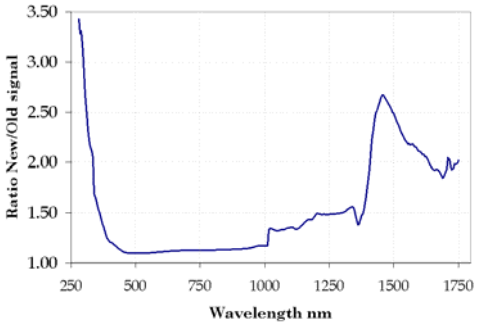

Fig. 2. Ratio of new to old throughput for improved PASS.

3.3 Pyrheliometer Characterization

Zero-offset signals (-5 to + 20 microvolts) are correlated with beam irradiance, rate of change of temperature, and wind speed. Five models to correct zero drift were developed from six months of 1-minute "shaded" pyrheliometer data. Models considered were independent parametric fits, multilinear regression with and without constant terms, and two component day/night, and three-component (nighttime/day low-wind/day high-wind) models. As shown in Table 1, the composite model produced the lowest mean error in correcting for zero drift.

Table 1. Mean residuals (bias error) for several model fits.

	Parametric	Day Night	Multilinear no Constant	Night Day high/low	Multilinear Constant
Count	259190	259190	259190	259190	259190
Mean	**0.00180**	**-0.0032**	**0.0115**	**0.0002**	**0.0238**
StDev	0.0233	0.0251	0.0251	0.02206	0.0188

3.4 New Radiometric Calibration Systems Performance

Three new radiometer calibration systems were implemented and tested in FY 2005: (1) new broadband outdoor radiometer calibration (BORCAL) data acquisition system (DAS) (Fig. 3a); (2) indoor pyranometer calibration system (Fig. 3b); and (3) new reference UV spectrometer. The new BORCAL DAS has 1/9th the zero offset of the previous system, and was integrated into our Radiometer Calibration and Characterization (RCC) system. Figure 4 shows that the new Kipp & Zonen indoor calibration system reproduces outdoor pyranometer calibrations with a precision of +/-2.0%. Two outlier instruments were identified for which differences of up to 7% were obtained, possibly due to spectral responsivity mismatch between the indoor lamp, outdoor sunlight, and detector paint absorption.

Fig, 3a. Afshin Andreas and new BORCAL DAS rack.

Fig 3b. Amy Bowen and Indoor Calibration System

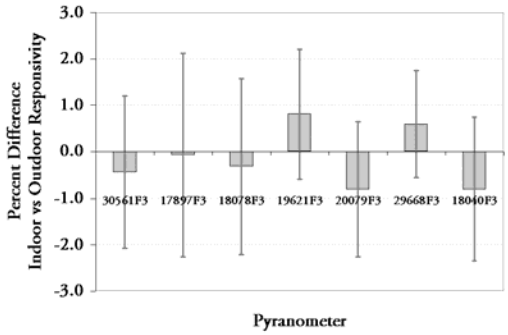

Fig. 4. Percent difference (2 sigma error bars) between BORCAL/RCC and indoor pyranometer calibration system responsivities

3.5. Replacement spectral measurement system

We assisted the PV measurements and characterization task with specifications and selection of a spectroradiometer system to replace obsolescent Li-COR spectrometers. As of September, 2005, a purchase order was placed for the selected system.

4. Conclusions

These advances assist PV researchers and industry to identify measurement artifacts, ensure accurate classification of PV products, reduce uncertainty in and improve solar radiometric data. ISO 17025 accreditation for PV reference cell calibration reinforces NREL quality data in support of the solar industry.

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MAJOR FY 2005 PUBLICATIONS

I. Reda, et al., Using a Blackbody to Calculate Net-Longwave Responsivity of Shortwave Solar Pyranometers to Correct for Thermal Offset During Outdoor Calibration Using the Component Sum Method, *Journal of Ocean Atmosphere Technology*

Myers, D.R. et al., An Update on Reducing the Uncertainty in Solar Radiometric Measurements, In Proceedings, SOLARIS 2005, 2nd International Conference on Solar Radiation Measurements and Models. May 25-26, Athens, Greece. Kambezidis, H. and Paissidis, G., Eds. pp 36-40. Kormos Publications, Athens, Greece.

Myers, D.R., et al. FY 2005 Midyear Progress Report Solar Radiometry and Metrology Task PVC57301 NREL/TP-56-37954 March 2005

Myers D.R., et. al. FY2005 Final Progress Report Solar Radiometry and Metrology Task PVC57301. Submitted Sep. 2005, In Press.

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